AKPIK 5: Poster

Time: Thursday 15:00–16:30 Location: P5

AKPIK 5.1 Thu 15:00 P5

ARTIFICIAL INTELLIGENCE in the automotive industry — •Ilya Anufriev — Moscow, Russia

Modern automotive industry is a high-tech industry where production and management processes require constant improvement in efficiency and cost reduction. The use of robotic conveyors and artificial intelligence technologies allows for significant results in optimizing production processes, improving product quality, and reducing operational costs. The leading trends in the automotive industry include automation of production processes, data analysis and demand forecasting, product quality management, logistics and supply chain management, and decision support. I have developed a model for implementing artificial intelligence to optimize workflows within an automotive organization.

AKPIK 5.2 Thu 15:00 P5

Physics-based Reinforcement Learning for Balancing the Cart-Pole — •Igor Polonskiy, Atreya Majumdar, and Karin Everschor-Sitte — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

Balancing a pole on a moving cart by applying lateral forces is a standard benchmark problem in reinforcement learning. Deep Q-Networks [1], which integrate reinforcement learning with neural networks, have been highly effective in solving this problem. Training the multiple hidden layers of Deep Q-Networks, however, is computationally expensive and thereby energy-demanding. Replacing these hidden layers with an Echo State Network reduces training costs while maintaining performance [2]. Echo State Networks have been shown to be replaceable by physical systems [3]. We explore the potential of solving the Cart-Pole problem with a physics-based Echo State Network.

[1] V. Mnih et al., Nature 518, 529 (2015)
[2] I. Polonskiy, Bachelor Thesis, University of Duisburg-Essen (11/2024)
[3] K. Everschor-Sitte et al., Nature Reviews Physics 6, 455 (2024)

AKPIK 5.3 Thu 15:00 P5

Stereovision-based angle and depth estimation for terahertz layer measurements — •Tim Arniko Meinhold[1,2], Dmytro Kharik[1], Joshua Hennig[1,2], Mirco Kutas[1,2], Jens Klier[1,2], Georg von Freymann[1,2], and Daniel Molter[1] — [1]Department for Materials Characterization and Testing, Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany — [2]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Terahertz systems can measure layer thicknesses with high precision in a fully contactless, non-destructive manner. However, reliable results require accurate alignment of the beam perpendicular to the surface, as even small angular deviations can affect the measurements. Many optical approaches still struggle to combine precision and real-time capability on demanding surfaces. Meanwhile, advances in stereo imaging and machine-learning methods provide a framework to support stable, interpretable measurement conditions.

Here, we report a compact stereovision-based setup within a framework that includes neural network-based approaches. Our goal is a practical and reliable method that delivers precise depth and angular information, which are expected to improve terahertz real-time thickness measurements.

AKPIK 5.4 Thu 15:00 P5

Exploring Reinforcement Learning for Particle Transport in the Presence of Inhomogeneities — •Finn Marten Boyer, Atreya Majumdar, and Karin Everschor-Sitte — University Duisburg-Essen, Duisburg, Germany

Classical transport theories typically assume homogeneous media, yet real materials often exhibit inhomogeneities that limit the applicability of such models. In particular, standard approaches like renormalization may fail when particles encounter defects whose characteristic energy scales are comparable to or larger than their kinetic energies. We investigate reinforcement learning as a data-driven framework for optimizing particle transport in strongly inhomogeneous environments. Our work indicates the potential of reinforcement-learning-based approaches for particle dynamics in more realistic and complex systems.

AKPIK 5.5 Thu 15:00 P5

Supporting Physical and Computational Biology with AI-Powered Multi-agent Model Generation — •Prerana Chandratre, Anjali Sharma, and Justin Bürger — TUD Dresden University of Technology, Dresden, Germany

Many open biological questions, from human embryogenesis to complex diseases like cancer, cannot be solved by experiments alone but require integration with biophysical and computational modeling. To address this, our group developed the software Morpheus (https://morpheus.gitlab.io/) which has become a widely used open-source platform (Starruß et al., 2014). Morpheus is based on a declarative modeling language, MorpheusML, and such models together with their biological context are collected in the MorpheusML model repository. Yet, creating MorpheusML models remains a barrier, especially for wet-lab researchers and students without programming expertise. To resolve this bottleneck, we are developing a model generation tool that uses a multi-agent workflow based on large-language models. Planned enhancements include a simulation-in-the-loop architecture enabling iterative, agent-driven model refinement and validation, expansion of the training dataset with model-text pairs from the MorpheusML model repository, and integration of automated validation and benchmarking metrics. The outcome will be the Morpheus.AI modeling assistant that enables robust generation of valid MorpheusML models from textual input sources, including PDF manuscripts. These AI-generated models will empower both research and education in physical and computational biology.

AKPIK 5.6 Thu 15:00 P5

Persistent Homology-Based Indicator of Orientational Ordering in Experimental Skyrmion Lattices — •Michiki Taniwaki[1,2], Thomas Winkler[1,3], Jan Rothörl[1], Raphael Gruber[1], Chiharu Mitsumata[4], Masato Kotsugi[2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany — [2]Department of Materials Science and Technology, Tokyo University of Science, Niijuku 125-8585, Japan — [3]Institute of Molecules and Materials, Radboud University, Heyendaalseweg 135, 6525AJ Nijmegen, The Netherlands — [4]Graduate School of Pure and Applied Sciences, University of Tsukuba, Tenodai 305-8571, Japan

Skyrmions are chiral spin textures whose topological protection makes them apt for low-power memory and logic devices. In two dimensions, skyrmion lattices can undergo topological phase transitions[1]. A central challenge is to quantify the configurational order of skyrmion lattices and to construct appropriate indicators that are sensitive to topological defects. Here we use persistent homology (PH), a method from topological data analysis, to characterize experimental two-dimensional skyrmion lattices. We define new scalar measures of translational and orientational order and compare them with the conventional measure of the ordering. Our approach captures the signatures of the softening of configurational order. These results demonstrate that PH provides a compact and robust indicator of the order and is well suited to the study of topological phase transitions. [1] R. Gruber et al., Nat. Nanotechnol. 20, 1405-1411 (2025).

AKPIK 5.7 Thu 15:00 P5

Hybrid Machine Learning Framework for Predicting Cycling-Induced Ageing in Lithium-Ion Batteries — •Sandhra Ganesh — University of Münster Institute of Physical Chemistry AK Heuer 48149 Münster, Germany

Predicting cyclical capacity fade is critical for assessing the long-term reliability and second-life potential of lithium-ion batteries. Traditional physics-based ageing models provide valuable interpretability but are often computationally expensive and depend on parameters that are difficult to obtain experimentally. Conversely, purely data-driven methods offer efficiency but typically struggle to generalise across operating conditions and lack physical grounding.This work proposes a hybrid modelling framework that integrates physics domain knowledge with deep learning to more accurately capture cycling-induced degradation. The framework incorporates physically meaningful feature extraction from voltage, capacity, and operational profiles, together with physics-guided constraints that ensure realistic degradation behaviour without requiring detailed mechanistic models. The approach aims to improve predictive accuracy, interpretability, and transferability across varying conditions and datasets. Its effectiveness will be evaluated through cross-condition generalisation studies and assessments of practical cycle-life prediction accuracy.

AKPIK 5.8 Thu 15:00 P5

Enabling high performance analog photonic computing using SFP transceivers — •Arvid Gansäuer[1], Mingwei Yang[1,2], Okan Akyüz[1,2], Lennart Mannteuffel[1], Felix Kübler[1], Konrad Tschernig[1], Enrico Stoll[1], and Janik Wolters[1,2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Institute of Space Research, German Aerospace Center (DLR), Berlin, Germany

Photonic analog processors promise energy-efficient, parallel computing, specifically to tackle future machine learning and artificial intelligence (ML/AI) workloads. The fundamental mathematical operation of ML/AI computations, vector-matrix multiplication, is naturally suited to be performed in an optical setting [1]. However, many approaches utilize specialized, custom-made light sources and modulators to encode input vectors [1,2]. In this work we use commercial 1550 nm SFP transceivers to encode these vector inputs. We employ the incoherent excitation approach, which enables the use of light pulses generated by independent transceivers without any phase stabilization. To encode vector elements as incoherent light amplitudes, we generate sequences of 0- and 1-pulses within a time bin shorter than the integration time of the measuring photodiode. Using an FPGA, we achieve parallel transmission of photonic signals via 4 transceivers at 1.25 GHz/N, where N is the number of intensity levels to approximate the analog signal. Thus, our approach enables the use of robust, readily available SFP-transceiver modules for high-performance analog photonic computing. [1] Y. Shen et al. Nat. Photon. 11, no. 7, p. 441 (2017), [2] J. Feldmann et al., Nature 589, no. 7840, p. 52 (2021).

AKPIK 5.9 Thu 15:00 P5

Understanding phase transitions in information processing systems using Geometric Thermodynamics — •Jonas Maximilian Müller, Ibrahim Talha Ersoy, and Karoline Wiesner — University of Potsdam

Phase transitions are well understood phenomena which arise in many fields of physics. Near the transition point very different systems show identical behaviour in accordance to their universality class. The framework of Geometric Thermodynamics allows for a more abstract approach to the transitions. We have shown, that neural networks undergo phase transitions related to accuracy hierarchies. However, the full extent of the analogy is unclear and there is no direct mapping of the critical phenomena described for DNNs to a thermodynamical framework. Luckily, both systems can at least locally be described using information geometry. In this study we characterise the transition phenomenology of well known thermodynamical systems using Geometric Thermodynamics. Using the Fisher metric we then construct a precise mapping between information processing systems, specifically DNNs, and thermodynamic systems in the proximity of the transition point. This mapping will in turn help us explore the full extent of the phase transition analogy for DNNs and better understand how they process information by leveraging the knowledge and techniques of Thermodynamics and Statistical Physics.

AKPIK 5.10 Thu 15:00 P5

Advancing Machine Learning Optimization of Chiral Photonic Metasurface: Comparative Study of Neural Network and Genetic Algorithm Approaches — •Davide Filippozzi[1], Alexandre Mayer[2], Nicolas Roy[2], Wei Fang[3], and Arash Rahimi-Iman[1] — [1]I. Physikalisches Institut and Center for Materials Research, Justus-Liebig-University, Gießen, Germany — [2]Department of Physics, Namur Institute for Complex Systems (naXys), University of Namur, Belgium — [3]College of Optical Science and Engineering, Zhejiang University, Hangzhou, China

We report on an advanced optimization framework for chiral photonic metasurfaces, comparing a refined Neural Network (NN) pipeline against a Genetic Algorithm (GA). By introducing a two-output NN architecture and exploiting geometric symmetries for data augmentation, we successfully reduce the trade-off between circular dichroism (CD) and reflectivity. Our comparative analysis on GaP and PMMA structures reveals complementary strengths: the GA excels in finding global optima for complex geometries, while the NN provides superior computational efficiency for large-scale screening. The optimized designs demonstrate a close to twofold increase in CD compared to Ref. [Mey & Rahimi-Iman, PSS-RRL 16, 2100571 (2022)]. We propose a hybrid workflow combining both methods to accelerate the design of effective chiral mirrors for polarization-selective light-matter interaction studies.

AKPIK 5.11 Thu 15:00 P5

Machine Learning for Tip Enhanced Raman Spectroscopy — •Harshit Sethi, Orlando Silveira, and Adam Foster — Aalto University, Espoo, Finland

Tip Enhanced Raman Spectroscopy (TERS) provides nanoscale chemical fingerprint alongside high-resolution topographic mapping of molecules, offering a powerful tool for materials discovery. However, TERS image datasets are challenging to interpret and typically demand time-consuming, computationally intensive quantum*chemistry calculations. To overcome this problem, we present an encoder-decoder model trained and evaluated on simulated TERS images of planar molecules, enabling direct prediction of molecular structures from spectral simulated data with high accuracy. Our approach demonstrates the feasibility of automating molecular structure identification from TERS images, bypassing traditional manual analysis. These findings provide a foundation for extending machine learning methods to experimental TERS datasets, potentially accelerating molecular discovery by integrating nanoscale spectroscopy with automated computational analysis.

AKPIK 5.12 Thu 15:00 P5

Non-unitary time evolution via the Chebyshev expansion method — •Aron Hollo[1,2], Daniel Varjas[3,4,5], Cosma Fulga[3,4], Laszlo Oroszlany[1,2], and Viktor Konye[3,4,6] — [1]Department of Physics of Complex Systems, Eötvös Loránd University, Budapest, Hungary — [2]Wigner Research Centre for Physics, Budapest, Hungary — [3]Institute for Theoretical Solid State Physics, IFW Dresden, Dresden, Germany — [4]Würzburg-Dresden Cluster of Excellence ct.qmat, Germany — [5]Department of Theoretical Physics, Budapest University of Technology and Economics, Budapest, Hungary — [6]Institute for Theoretical Physics Amsterdam, University of Amsterdam, Amsterdam, The Netherlands

The Chebyshev expansion method is a highly efficient technique for computing the time evolution of quantum states in Hermitian systems with bounded spectra. In the physics literature, its applicability is often assumed to be restricted to real spectra within the interval [-1,1], limiting its use for non-Hermitian dynamics.

Here, we show that this restriction is not fundamental. The Chebyshev expansion of the exponential function remains mathematically valid over the entire complex plane and can therefore be applied to arbitrary non-Hermitian matrices. The apparent breakdown of the method outside the conventional spectral bounds is traced back to numerical rounding errors rather than to a failure of the expansion. By deriving an analytic upper bound for the accumulated rounding error, we obtain a practical criterion for selecting safe time steps based on the spectral radius of the Hamiltonian.

AKPIK 5.13 Thu 15:00 P5

Nanomechanics-Driven Design of Flexible Textile-Based Metamaterials and Bio-Inspired Soft Composites — •Amine HAJ TAIEB — ISAMS, University of Sfax, Tunisia

Textiles, soft composites, and architectured metamaterials are emerging as key platforms for next-generation flexible systems in wearables, biomedical devices, adaptive structures, and energy-absorbing applications. Their unique mechanical performance*combining flexibility, stretchability, and durability*originates from complex interactions across multiple length scales, from fiber and yarn nanostructure to textile architecture and macroscopic response. Despite rapid progress, the lack of an integrated multiscale understanding still limits predictive design. This contribution explores how advanced nanomechanical characterization and multiscale modeling can accelerate the rational design of textile-based and bio-inspired flexible materials. Inspired by biological fibrous systems, we further discuss how hierarchical structuring and architectured textile geometries can be exploited to tune mechanical functionality. The integration of high-throughput testing and data-driven approaches, including machine learning, enables the identification of key design descriptors governing mechanical adaptability and robustness. By promoting interoperable experimental and simulation data, this work directly ontributes to a unified framework for the design of sustainable, high-performance textile-based flexible materials and metamaterial

AKPIK 5.14 Thu 15:00 P5

A Finite Element Homogenization Approach for Hollow Conductor Windings — •Shamim Aslam, Laura D'Angelo, and Herbert De Gersem — Institute for Accelerator Science and Electromagnetic Fields, TU Darmstadt, Germany

Future fast cycling synchrotrons require fast ramping dipole magnets. Due to high transients, eddy current and hysteresis effects become more pronounced in these magnets. Consequently, the associated thermal losses must be carefully considered in the overall magnet design. One key design solution to address this challenge is the use of hollow conductors. Hollow conductors facilitate the flow of electrical current while enabling efficient thermal cooling. Simulation-wise, hollow conductors are very challenging to compute as they impose a multi-scale problem, both geometrically and physically. The computational cost for multiscale geometries can be potentially reduced by using homogenization technique. We present an advanced homogenization technique for the simulation of hollow conductor windings, tackling this multi-scale problem while maintaining a sufficient accuracy. In this homogenization technique, the fine model containing hollow conductor windings replaced with a bulk region with equivalent material properties. As a validation of the homogenization technique, the method applied on a dipole magnet with 16 hollow conductors windings. This application example demonstrate the high accuracy, reduced computation time and easy implementation of our homogenization technique as compared with the brute force finite element simulations.

AKPIK 5.15 Thu 15:00 P5

Digital-Analog Simulations of Schrödinger Cat states in the Dicke-Ising Model — •Dmitrii Shapiro[1], Yannik Weber[1], Tim Bode[1], Frank K. Wilhelm[1,2], and Dmitry Bagrets[1,3] — [1]Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, Germany — [2]Saarland University, Germany — [3]University of Cologne, Germany

We study the Dicke-Ising model: an Ising chain where all spins couple to a common bosonic mode. Due to competing spin-spin and spin-boson interactions, the phase diagram exhibits both second- and first-order superradiant quantum phase transitions (QPTs). At the QPT, the system evolves into an entangled superradiant state with a boson condensate. We discuss the free-energy landscape near the QPT, obtained by integrating out the spins. We then propose a digital-analog quantum simulator for the Dicke-Ising Hamiltonian based on interacting qubits coupled to a single-mode resonator. The many-body propagator is decomposed via Trotterization into layers of single- and two-qubit rotations alternating with Jaynes-Cummings (JC) gates that emulate spin-boson coupling. The JC gate is analog, as it exploits rotations in the resonator's native Hilbert space. We show that the superradiant state can be approximated by a quench protocol with a finite-depth circuit. Applying a selective measurement of global qubit parity yields a Schrödinger cat state in the photonic subspace—a hallmark of the superradiant ground state in finite-size systems. The cat state can be probed via Wigner tomography of the resonator field. For details, see [Shapiro et al., PRA 112, 042412 (2025)].